IEEE 1451: A Standard in Support of Smart Transducer Networking

Kang Lee

National Institute of Standards and Technology
100 Bureau Drive Stop 8220
Gaithersburg, Maryland 20899-8220 USA
Phone: (301) 975-6604, Fax: (301) 990-3851, E-Mail: kang.lee@nist.gov

Abstract

The IEEE (Institute of Electrical and Electronics Engineers) 1451 smart transducer interface standards provide the common interface and enabling technology for the connectivity of transducers to microprocessors, control and field networks, and data acquisition and instrumentation systems. The standardized Transducer electronic Data Sheet (TEDS) specified by IEEE 1451.2 allows the self-description of sensors and the interfaces provide a standardized mechanism to facilitate the "plug and play" of sensors to networks. The network-independent smart transducer object model defined by IEEE 1451.1 allows sensor manufacturers to support multiple networks and protocols. Thus, transducer-to-network interoperability is on the horizon. The inclusion of P1451.3 and P1451.4 to the family of 1451 standards will meet the needs of the analog transducer users for high-speed applications. In the long run, transducer vendors and users, system integrators, and network providers can all benefit from the IEEE 1451 interface standards.

1. Introduction

The marketplace is demanding devices, appliances, and systems with better capabilities and higher levels of functionality. Sensors, used in these devices and systems to provide information on the parameters being measured or to identify the states of control, are good candidates for increased built-in intelligence. Microprocessors can make smart sensors or devices a reality. With this added capability, it is possible for a smart sensor to directly communicate measurements to an instrument

model. An application model of the IEEE 1451 standards in distributed measurement and control applications is also addressed.

The sensor market, which is expected to grow to $43 billion by 2008, is extremely diverse. Sensors are used in most industries and are going global [5]. In this very competitive market, sensor manufacturers are seeking ways to add new technology to build low-cost, smart sensors that meet the continuous demand for more sophisticated applications and ease of use. Networking is becoming pervasive in various industrial settings. It is causing a major shift in the measurement arena. In any application, decisions about the use of sensors, networks, and application software can all be made independently, based on the application requirements. In reality, however, all these function modules cannot be easily integrated due to the lack of a set of common interfaces.

2. The Smart Transducer Interface Projects

A typical sensor or control network consists of network nodes comprised of up to 256 units linked by multi-wire cables. Each network node contains a microprocessor device. A sensor or multiple sensors can be connected to each node through an electronic interface. Every network on the market has its own custom-designed interface for sensors. Sensor manufacturers have to expend tremendous efforts to support numerous networks and protocols. The purpose of the IEEE P1451 project, Standards for Smart Transducer Interface for Sensors and Actuators, is to define a set of common interfaces for connecting transducers to microprocessor-based systems, instruments, and field networks in a network-independent fashion [6].

means for achieving transducers-to-network interchangeability and transducer-to-networks interoperability. During the standards development process, this idea was implemented in prototype interfaces with various sensors that could plug and play with different control networks – DeviceNet**, LonWorks, and Smart Distributed System (SDS) as shown in Figure 1.
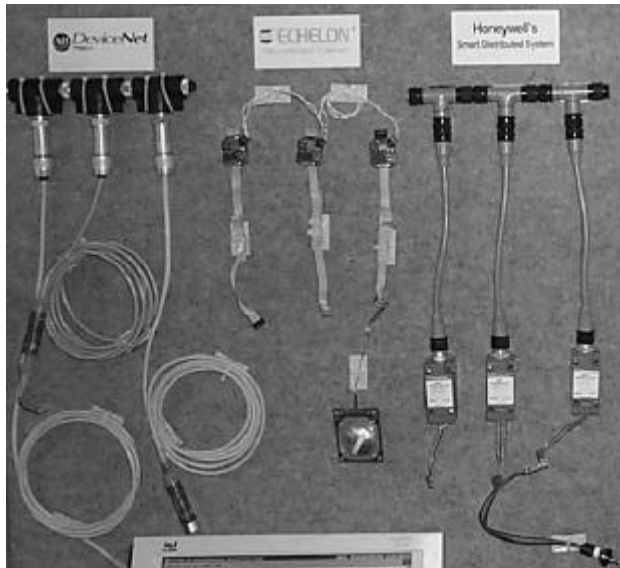

Figure 1. Sensors plug-and-play to different control networks with the proposed interfaces

2.1 IEEE 1451.2 - Transducer-to-Microprocessor Communication Interface

The IEEE 1451.2 project defines a Transducer Electronic Data Sheet (TEDS) and its data format, along with a 10-wire digital interface and communication protocol between transducers and a microprocessor [7]. The framework of the IEEE 1451.2 interface is shown in Figure 2. The TEDS, stored in a nonvolatile memory, contains fields that describe the type, attributes, operation, and calibration of the transducer. With a requirement of only 178 bytes of memory for the mandatory data, the TEDS is scaleable. A transducer integrated with a TEDS provides a feature that makes the self-description of transducers to the network possible. Since the transducer manufacturer data

Up to 255 sensors or actuators of various digital and analog mixes can be connected to a STIM. The STIM is connected to a network node called NCAP through the 10-wire Transducer Independent Interface using a modified Serial Peripheral Interface (SPI) protocol for data transfer.
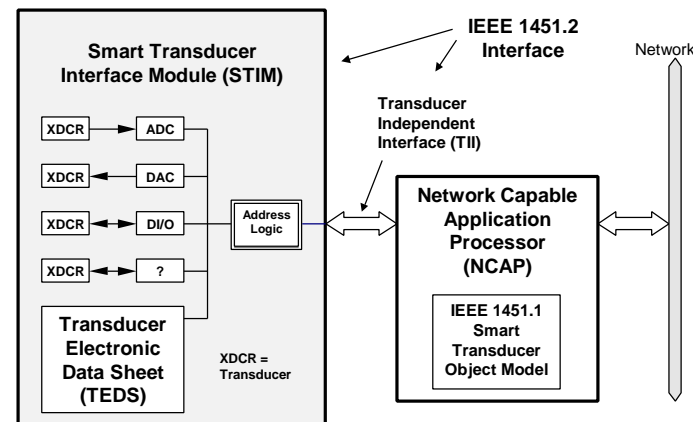

Figure 2. Framework of IEEE 1451.1 and 1451.2 Interfaces

2.2 IEEE 1451.1 – Networked Smart Transducer Model

The IEEE P1451.1 project defines a common object model for a networked smart transducer and the software interface specifications for each class representing the model [9]. Some of these classes form the blocks, components, and services of the conceptual transducer. The networked smart transducer object model encapsulates the details of the transducer hardware implementation within a simple programming model. This makes programming the sensor or actuator hardware interface less complex by using an input/output (I/O)-driver paradigm. The network services interfaces encapsulate the details of the different network protocol implementations behind a small set of communications methods. The model of the networked smart transducer is shown in Figure 3.
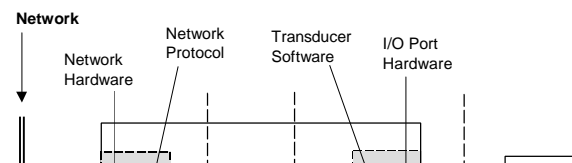
Figure 3. Networked Smart Transducer Model

2.3 IEEE P1451.3 – Distributed Multidrop System for Interfacing Smart Transducers

During the course of the development of the IEEE 1451.1 and 1451.2 standards, some sensor manufacturers and users recognized the need for a standard interface for distributed multidrop smart sensor systems. In a distributed system a large array of sensors, in the order of hundreds, needs to be read in a synchronized manner. The bandwidth requirements of these sensors might be relatively high, in the order of several hundred kilohertz, with time correlation requirements in tens of nanoseconds. The IEEE P1451.3 project was created to define the specification for such a standard. The physical representation of the proposed IEEE P1451.3 standard is shown in Figure 4. A single transmission line is proposed to be used to supply power to the transducers and to provide the communications between the bus controller and the Transducer Bus Interface Modules (TBIM). A transducer bus is expected to have one bus controller and many TBIMs. A TBIM may contain one or more different transducers. The NCAP contains the controller for the bus and the interface to the network that may support many other buses.
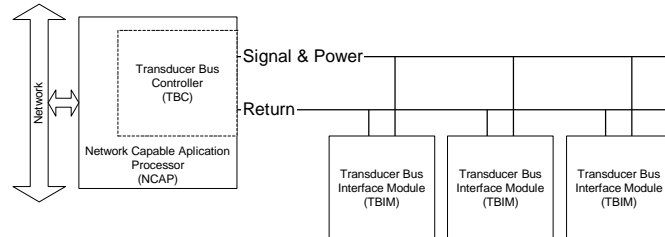
Figure 4. Physical Representation of the IEEE P1451.3

2.4 IEEE P1451.4 – Mixed-mode Transducer and Interface

In the condition-based monitoring and maintenance industry, analog transducers such as piezoelectric, piezoresistive, and accelerometer-based transducers are used with electronics instruments to measure the conditional state of machinery.

List contains the identifications of the other nodes. In order to reduce cabling and interfacing costs, a model using different wiring configurations is chosen as a transducer connection interface. If a single wire model is used, the analog transducer signal transmission and communication of the digital TEDS data to an instrument or a network are done on the same wire, but at separate times. If a multi-wire model is used, communication of digital data and analog signals can be accomplished simultaneously. The digital communication can be used to read the TEDS information and to configure an IEEE P1451.4 transducer. The context of the mixed-mode transducer and its interface(s) are shown in Figure 5.
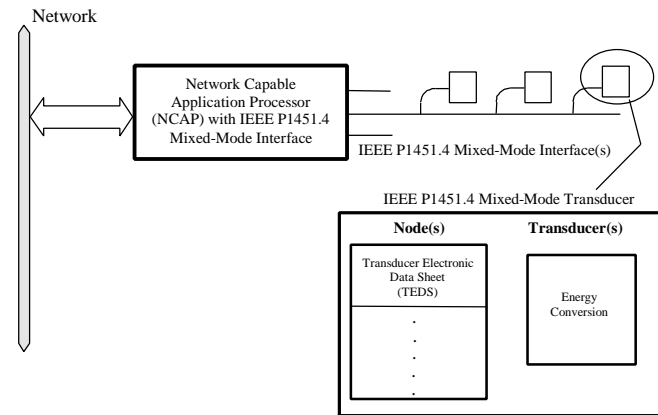
Figure 5. Context of Mixed-mode Transducer and Interface

3. An Application of IEEE 1451-based Sensors on a Network

A distributed measurement and control system can be easily designed and built based on the IEEE 1451 standards [10]. An application model of IEEE 1451 is shown in Figure 6. Three NCAP/STIMs are used for illustration purposes. In scenario one, with sensors and actuators connected to the STIM of NCAP #1, application software running in the NCAP can perform a localized control function, for example, maintain a constant temperature of a bath. The NCAP reports measured data, process information, and control status to a remote monitoring station or host. It frees the host from the processor-

across the Internet. Recently, instrument manufacturers are moving toward TCP/IP network interfaces. This technology has migrated into sensor networks as well. An industrial Ethernet NCAP that is IEEE 1451.2 compatible can be acquired easily to build web-based distributed measurement and control applications, which will enable the access of sensor information and measurements across the Internet [10].
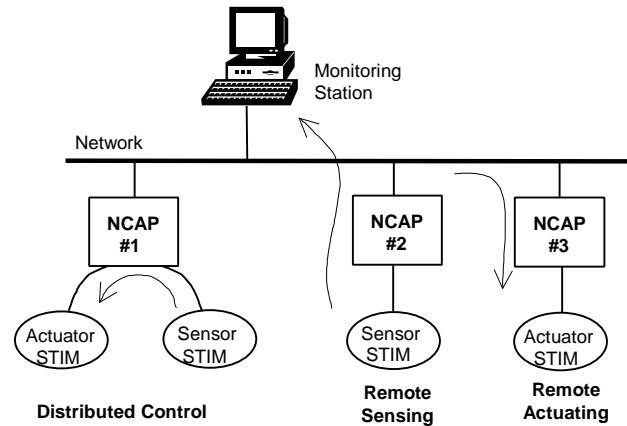

Figure 6. An Application of IEEE 1451-based Sensors on a Network

4. Summary

The IEEE 1451 smart transducer interface standards are defined to allow a transducer manufacturer to build transducers of various performance capabilities that are interoperable within a networking system. The standards, on one hand, allow for simple devices with relatively low data sampling rates and moderate time correlation requirements to be built. On the other hand, bandwidth requirements to several hundred kilohertz and time correlation requirements in the range of nanoseconds are also addressed. The IEEE 1451 standards have provided the common interface and enabling technology for the connectivity of transducers to microprocessors, control and field networks, and data acquisition and instrumentation systems. The standardized TEDS specified by IEEE 1451.2 allows the self-description of sensors. It also provides a standardized mechanism to facilitate the "plug and play" of sensors to networks. The network

6. References

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